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ABSTRACT

Virtual reality is a newly emerging tool for scientific visualization that makes possible multisensory, three-dimensional modeling of scientific data. While the emphasis is on visualization, the other senses are added to enhance what the scientist can visualize. Researchers are working to extend the sensory range of what can be perceived in virtual reality. Virtual reality technology is still fairly primitive, but advances can be expected to extend the use of virtual reality in telerobotics, telepresence surgery, virtual chemistry, virtual planetary travel, virtual entertainment, and architectural design. Most professional applications of virtual reality are extremely expensive, but some low-cost systems make it possible to get a taste of the virtual reality experience. These systems are listed, and an eight-item list of resources for further information is included. (Contains 15 references.) (SLD)

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Virtual Reality: Visualization in Three Dimensions

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by
Hilary McLellan

We have arrived at the post-Columbus paradigm of exploration (Teixeira, 1992). In 1492 Columbus sailed the ocean blue...He traveled by ship, the technology of his day. Columbus went with his ships to the site of his exploration in person. Today, in the post-Columbus age, we send our technology ahead of us as we explore the universe. The technology of our day that makes this possible is virtual reality. With virtual reality, explorers can explore Mars via "virtual travel." Scientists can explore worlds that are too small for us to see, such as atoms and molecules, with virtual reality. Doctors can explore the human body, and even conduct "telepresence" surgery, without directly seeing or even touching the patient's body. Another example of virtual exploration is the virtual kitchen, developed by Mitsubishi in Japan, where consumers can select a kitchen with the appliances they want and, a short time later, the real kitchen is actually delivered and installed, based on their design choices in the virtual kitchen. Similar to this is wheelchair VR; people who are wheel-chair bound can field-tested building designs via virtual reality to determine if the design provides necessary access for those who are wheelchair-bound. Stock market analysts can explore and analyze financial data with the help of virtual reality (Teixeira, 1992). The virtual financial data consists of an ocean of icons representing different stocks, with rising and lowering rates. The behavior of the icons, such as blinking and spinning, represents different kinds of patterns. It is possible to move in close to look at information in detail. Ideally, this will permit Wall Street to represent much more information graphically in a way that is accessible to human analysts. Ultimately it will be possible to create and explore worlds that exist only in our imaginations and in virtual reality.

Virtual reality is a newly emerging tool for scientific visualization that makes possible multisensory, three-dimensional modeling of scientific data. A virtual reality system does more than make 3-D pictures: it gives the user the illusion of walking around in the 3-D scene. Virtual reality offers scientists the ability to work surrounded by images of molecules and other objects that they once had to use an electronic microscope to study. In addition to trying to immerse users into virtual worlds, scientists are using the virtual reality technology to augment the normal senses --- sight, touch, hearing, and even smell. At the MIT Media Lab, Margaret Minsky and other researchers are developing electronically simulated textures. With virtual reality, the emphasis is on visualization, with three-dimensional graphics, but the other senses are added to enhance what the scientist can "visualize." This includes haptic visualization, involving the sense of touch, and three-dimensional audio. Virtual smells are also envisioned. Researchers are working to extend the sensory range of what can be perceived in virtual reality to include electronically simulated textures, resistance, sound, and other forms of

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response. Robinett (1991) claims that the real power of immersive virtual reality technology "is that it can help you perceive the real world in ways that were previously impossible. To see the invisible, to travel at the speed of light, to shrink yourself into microscopic worlds."

There are two kinds of virtual reality. One type of virtual reality is an attempt to make a realistic representation of a world around us. Here the goal is to simulate a real surrounding. In the second type of virtual reality, the real reality is too complex to dealwith, so the goal is to create a simplified reality that facilitates insight and decision-making.

Robinett (1991) describes virtual reality as "a 3D video game you can enter by strapping something onto your face that fools your senses into perceiving an environment that surrounds you on all sides. The thing strapped to your face is called a Head-Mounted Display." The Head-Mounted Display contains a magnetic sensor whose precise position is tracked by a small box on a wall or ceiling nearby. Every time the person in the goggles moves her head, the tracker transmits this 'data' to the computer, which, in turn, changes the scene viewed in the goggles with only the slightest delay. When the user turns and looks to the left, or the right, the computer-generated scene shifts accordingly. This makes huge demands on computer memory and processing.

In virtual reality, the user is placed inside the image; the generated image is assigned properties which make it look and act real. The user enters the computational space rather than merely observing what's on a computer screen and interacting with it via keyboard or mouse. Instead of keyboard and mouse, there is now the Data Glove with electronic sensors and a head mount with stereoscopic goggles showing what would normally be viewed on the computer screen. Both the glove and the goggles are interfaced with the computer.

The Data Glove transmits and receives data so that the computer generated image responds to the movements of the user's hand, encased in the glove, as well as responding to the user's head movements, tracked by the Head-Mounted Display. A three dimensional model of this glove appears in the image shown in the goggles. This three dimensional model of the glove moves in correspondance with the user's hand movements in the real glove. The model of the glove provides an indicator of the user's position within the virtual space to orient the user. Pointing the glove moves the user through the virtual space. The user is not limited to horizontal movement in the virtual space; it is possible to move up to get a birds-eye view or to move down to get a closer look. And it is possible to move through 'virtual' walls and furniture.

Interactions with virtual environments are not constrained to only viewing. The user can interact with objects and spaces in VR. For example, the user can use tools to create new environments, to modify old ones, to fix errors, or to play. It is possible to interface with a virtual keyboard or to use voice commands to select options from a virtual screen menu. It is possible to manipulate virtual tools by making the appropriate hand gestures which are transmitted through the Data Glove to the computer, which directs the virtual glove to simulate those movements.

At this point, virtual reality technology is still fairly primitive: the motion of images are jerky and the computer-generated objects look more like cartoons than the real thing. The quality of the computer graphics in these systems is very poor by comparison with the photo-realism that is possible on the screens of high-resolution color monitors (Wheeler, 1991). This is because the vast quantities of data needed to portray a complex three dimensional image that must be revised every time the user's head moves.

Telerobotics

Virtual reality applications have been designed to direct and control the activities of robots at a distance. These robots may be used in space exploration or they may be used in dangerous settings where humans cannot safely go, for example nuclear power plants. A video camera in the robot's head permits the human operator to see what the robot sees, transformed into three dimensions with computer processing, which is viewed through the Head-Mounted Display. The hands of the telepresence robot allow the human operator to manipulate objects at the robot's location, by means of virtual reality (National Aeronautics and Space Administration, 1988). Telemanipulators are used to handle radioactive fuel in nuclear reactors. Teleoperated robots are beginning to be used to fight fires and defuse bombs. (p. 21)"

Telepresence Surgery

Richard Satava (1992), a military surgeon, is developing a telepresence surgery application to enhance laparoscopic surgery (removal of the gall bladder). Recent innovations in video technology have allowed direct viewing of internal body cavities such as the abdomen, through natural orifices or tiny incisions, instead of surgery involving large incisions and directly visualizing and touching the internal organs and tissues. This type of surgery is less invasive, resulting in less serious side effects, faster recovery, and lower insurance costs.

Traditionally, laparoscopic surgery involving noninvasive techniques has serious limitations in terms of the surgeon's ability to visualize the organs and lack of flexibility of the instrumentation. In the telepresence surgery system, the surgeon never touches the patient (after the preliminary incisions are made). Organs can be removed without directly touching or seeing them. With telepresence, there is a master-slave relationship between the instruments manipulated directly by the surgeon and the robotic instruments carrying out the surgery. Once this is fully developed, it will make it possible to conduct surgery at a distance: on the battle field, in space, or across the globe in a remote location.

Virtual Chemistry

At the University of North Carolina, Chapel Hill, a virtual reality system is used to help chemists explore the force-fields that bind molecules together or cause them to repel one another (Rheingold, 1990). In addition to three dimensional graphics that help chemists see the microscopic molecules at an enlarged scale, a force feedback arm simulates feedback pressure based on the force-fields. This helps scientists sense where to dock individual molecules into a combination of molecules, based on mutual attractions and repulsions. If two molecules repulse each other, they won't combine well, but if they attract, one can be docked to the other to form links in a chain of molecules. This research can help biochemists searching for targets on protein where they can attach drugs.

Virtual Planetary Travel

Virtual planetary travel is the application of telepresence involving unmanned rovers to planetary surface exploration (McGreevy, 1989). A planetary terrain visualization computer system provides dynamic interaction with planetary terrain data, for example data collected and relayed back to earth by Landsat or the Voyager Space Probe as well as unmanned space rovers and probes such as the Surveyor probe which made several landings on the moon. Currently this system is being applied to Mars and Earth. An example of virtual planetary travel, L.A.: The Movie, can be see on the videodisc (or videotape) State of the Art of Computer Animation (SIGGRAPH, 1987). An example of virtual planetary travel to Mars, Mars: The Movie, developed at the Jet Propulsion Laboratory in Pasadena, California, can be seen on Knowledge Navigator (Apple Computer, Inc., 1990).

Virtual Field Trips

There are many potential applications for virtual reality in education. Virtual reality or 'telepresence' field trips are already a part of the JASON Project (EDS, 1991). The JASON Project transports thousands of North American students via satellite to sites where scientists are uncovering historic discoveries and, through sophisticated data links, allows these students to become hands-on participants. At the interactive downlink sites for the JASON Project, three enormous video monitors give students a window on the action of scientific discovery. The focus of the research is JASON Jr., a 200-pound remotely operated vehicle (ROV) equipped with video cameras that can explore thousands of feet below the ocean's surface. Students at the downlink sites can talk to the scientists; they can also operate JASON Jr., directing its movement single-handedly, by means of a joystick and digital data link. Scientists are able to interact with students individually, as well as exchange questions and answers among the entire group.

Kellogg, Carroll, & Richards (1990) envision another potential educational application of virtual reality in their scenarion of a Visit to the Natural History Cyberspace Museum. This application does not yet exist, but it is nonetheless exciting:

Charles takes one of the empty seats associated with the exhibit in order to enter its habitat cyberspace. A monitor at the back of his seat will show curious onlookers what he is seeing. Activating the cyberspace, as he has done many times before, the goggles Charles is wearing opaque for a moment before he is suddenly swept into the virtual landscape of Archaeopteryx. As he orients and looks around, Charles sees one of the birds sitting on a low-hanging branch in a nearby tree. He approaches the tree and reaches out a virtual hand to touch the bird. As he makes contact, Charles's perception shifts as he takes on the perspective of the bird. As he makes contact, Charles's perception shifts as he takes on the perspective of the bird and surveys the landscape from his perch. Presently, he spots what he is looking for: he sees a coelurosaur on a distant ridge. He jumps down from the tree and runs toward the ridge. Confronting the beast, Charles again reaches out a virtual hand to touch it. His perception shifts again as he "becomes" the dinosaur. The bird stands nearby.

Virtual Entertainment

Virtual reality is having a big impact on entertainment, as evidenced by the Battle Tech game and the Dactyl Nightmare arcade game. Jonathon Waldern (1992), the British VR pioneer whose company W Industries produced Dactyl Nightmare, is developing a VR game where four users are linked together to serve as a team to fight the villains created by the computer. This system contains 100 rooms, each with a different scene. Players can choose which character and which characteristics they want, including not only appearance, but the voice they want, using a vocalizer to change voice characteristics to match the character. Waldern has also reported that the first VR theme park is in development. And a virtual reality game show will begin airing on British television in December 1992.

Architectural design

"Architectural walkthroughs" make it possible for architects and their clients to get a first-hand feel for the spaces they design, before the buildings are actually built. This enhances communication between the architect, who has highly developed visualization skills, and the client, whose visualization skills are not as highly developed. This application has been adapted to use by the differently abled, who can 'walkthrough' or 'wheelchair through' a building in the design stage and give the architect feedback on design features, such as the height of wall switches and kitchen

cabinets.

Low cost VR Systems

Most professional applications of virtual reality require technology costing $50,000 and more. However, it is now possible to assemble hardware and software that make it possible to demonstrate virtual reality for about $200 (not counting the computer itself). Low cost virtual reality interfaces and applications are available for Macintosh and Amiga platforms. These applications do not have anywhere near the full power of the more expensive technology, but they do make it possible for you and your students to get a taste of the computer interfaces and applications that are on the horizon in the field of computer science. Mostly these low cost computer applications are limited to 3-D graphics programs, but there are some applications that include 3-D glasses or a Power Glove interface.

Amiga

1. Haitex 3-D System

Shawn Glisson of Haitex Resources, Inc., offers a very impressive system for about $200. This system includes 3-D software and electronic 3-D goggles. It operates on the Amiga with a standard mouse interface rather than a glove. This is the most impressive low-cost VR system I have seen. The graphics are excellent and the program provides a powerful and flexible design platform.

2. DIGI-Mice

The DIGI-Mice program from Tensor Productions is a software program, costing about $90.00, that makes it possible to interface the Power Glove (from Mattel Toys) with the Amiga computer for certain limited applications, such as a music program that comes together with the interface control program.

3. Virtual Reality Studio

Virtual Reality Studio, from Domark is a 3-D construction set software program for creating solid-modeled, animated "realities" and games, using the mouse as the interface device. With Virtual Reality Studio, it is possible to chain locations together to create worlds; for example, linking the rooms in a house. VRS has a built-in programming language that uses BASIC-like syntax and commands for animation and sound. Virtual Reality Studio has its limitations, including a limited graphics palette, but nonetheless it is a powerful program that puts a commercial- grade development system in the hands of consumers, giving a sense of what is possible with virtual reality. This program does not interface with any kind of either a Power Glove or Head Mounted Display device.

Macintosh

1. StereoMac 3-D

For the Macintosh, the StereoMac 3-D package is available from the 3-D TV Corporation for $195. This package includes: 1) an electronic 3-D stereovisor (Sega glasses); 2) a stereoscopic interface that can be used with the Macintosh Plus, SE, or II series computers; and 3) a diskette with several 3-D demos and source code in THINK C language, Version 4.0. The demos were developed by Juri Munkki of the Helsinki University of Technology in Finland. These demos include dynamic 3-D pictures of a spiral, a rotating Macintosh computer, and a maze, presented with a small 2-D map for navigation. You navigate the maze by holding down the button while moving the mouse.

2. Virtus Walkthrough 1.03

Another virtual reality program for the Macintosh is Virtus Walkthrough 1.03, a CAD (Computer-Aided Design) program for 3-D drawing and visualization that lets you "walk through" your ideas for spatial design. Virtus Walkthrough 1.03 contains an integrated set of modeling and presentation tools that make it possible for architects, engineers and other designers to create and communicate their ideas. This program has a user-friendly interface. It costs $259.

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Wheeler, D.L. (March 31, 1991)- Computer-created world of 'Virtual Reality' opening new vistas to scientists. *The Chronicle of Higher Education*. 37 (26), A6+.

Resources

Some resources for exploring virtual reality in greater depth include:

1. Rheingold, H. (1991). *Virtual reality*. New York: Summit Books. Excellent overview of the entire field of virtual reality for the nonspecialist; the history of its development and emerging trends. Howard Rheingold is a thoughtful writer who has been covering developments in computing and related fields for over a decade.

2. Krueger, M. (1991). *Artificial reality II*. Reading, MA: Addison-Wesley. An Excellent overview of one branch of virtual reality, artificial reality, by its inventory, Myron Krueger. Contains excellent photographs and diagrams

showing the full range of VR technologies as well as a good glossary of VR terms. A commercially produced artificial reality system, Mandala, is available for about $300.00 (plus the cost of hardware).

3. Helsel, S. (Ed.) (1990). Virtual reality: Theory, practice, and promise. Westport, CT: Meckler. Presents articles by several virtual reality researchers about their work. Sandra Kelsel is the editor of TheMultimedia Review, also published by Meckler, a quarterly journal that features articles about virtual reality and other multimedia.

4. Benedikt, M.L. (Ed.) (1991). *Cyberspace: The first steps.* Cambridge, MA: MIT Press. This book will be released October, 1991. It will contain articles by a wide range of authors, including the science fiction writer William Gibson (who coined the term cyberspace), and authors from Lucasfilm Ltd., Autodesk, IBM, Texas Instruments, and various universities.

5. McLellan, H. (1992) *Virtual reality: A selected bibliography.* Educational Technology Bibliography Series. Englewood Cliffs, NJ: Educational Technology Publications. Volume Six.

6. Media Magic (1990). Virtual Reality. [Videotape]. Media Magic, Nicasio, CA 94946. Tel. (415) 662-2426. $60.00. This video documents virtual reality technology and applications at VPL Research, the NASA Ames Research Laboratory, the University of North Carolina, and the Massachusetts Institute of Technology.

7. JASON Projects, EDS, 7171 Forest Lane, C001, Dallas, TX 75230. Tel. (214) 661-6516.

8. Houseman, Linda, Computer Science Department, University of North Carolina, Chapel Hill, NC 27599-3175. Reprints of articles about virtual reality at the University of North Carolina.

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